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3,271,702

COAXIAL TRANSFER SWITCH

Filed Oct. 17, 1960

4 Sheets-Sheet 1

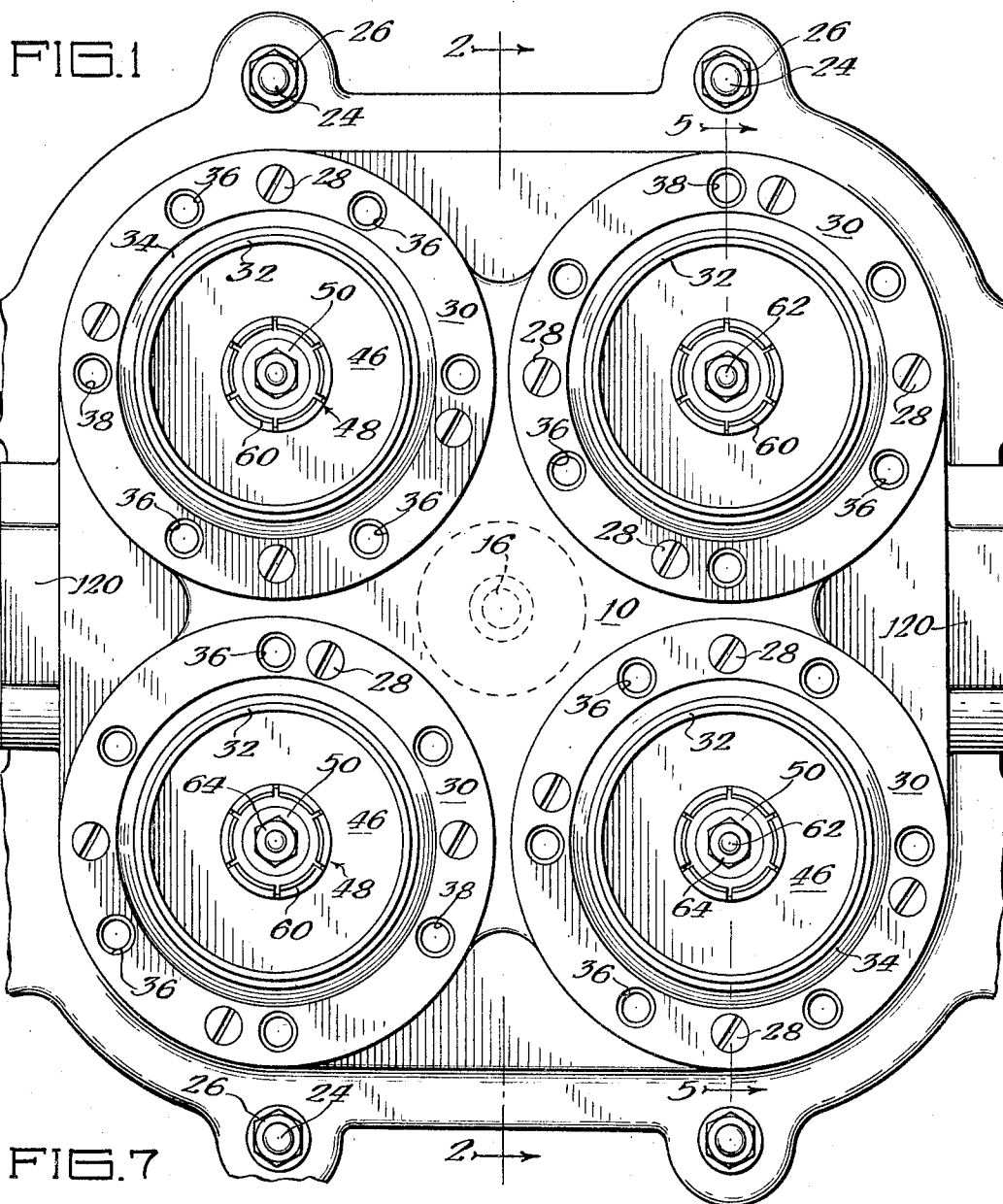


FIG. 7

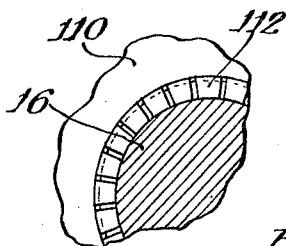
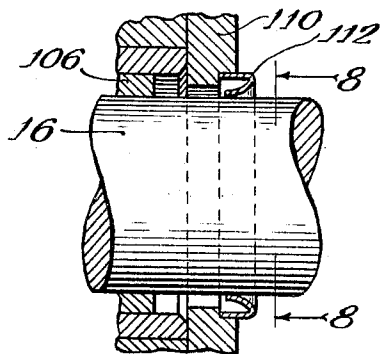


FIG. 8

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FIG. 3

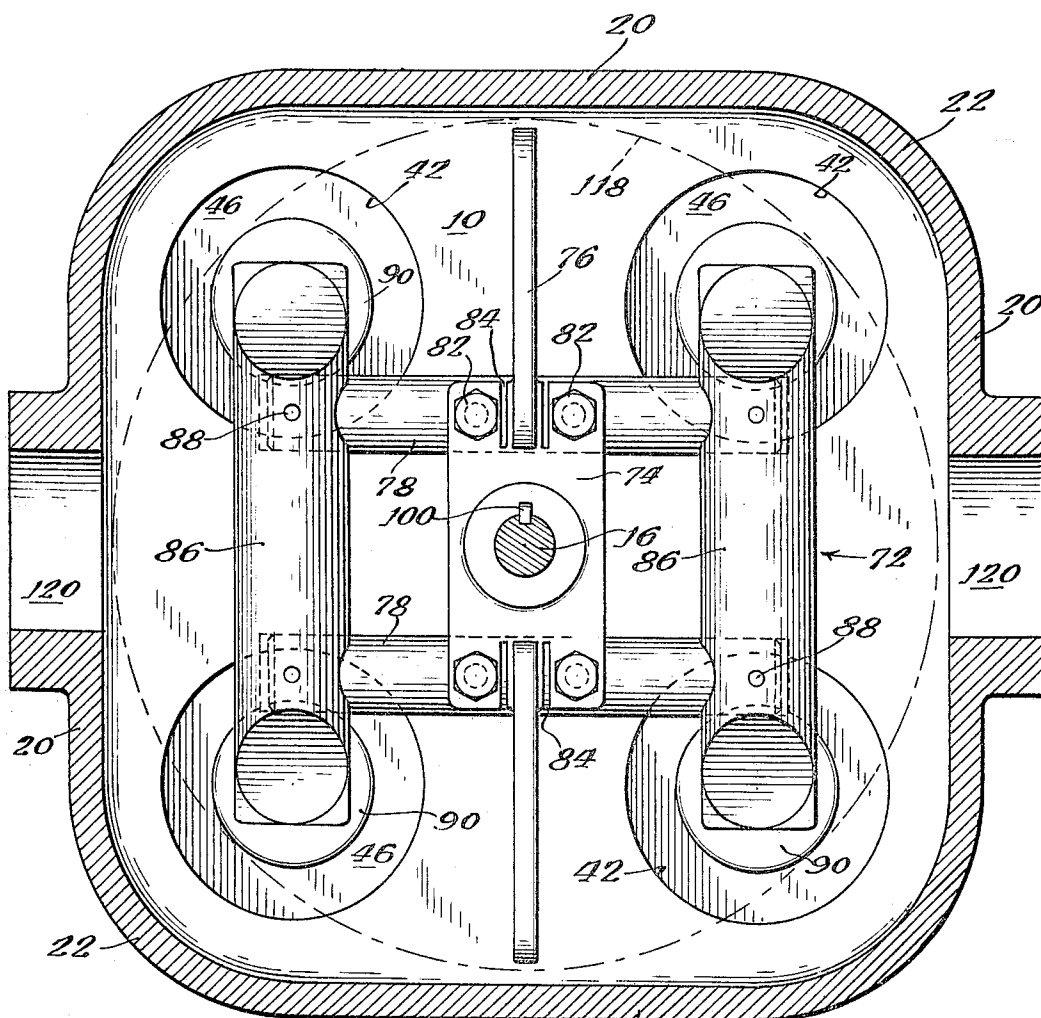
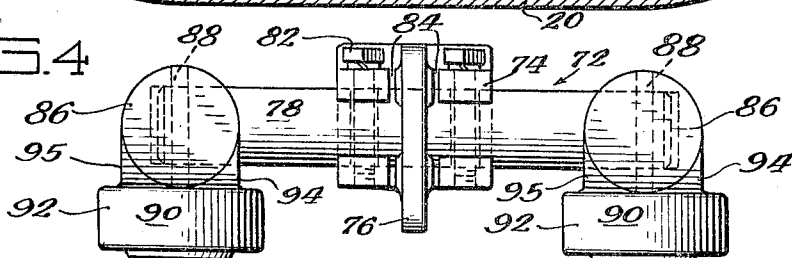


FIG. 4



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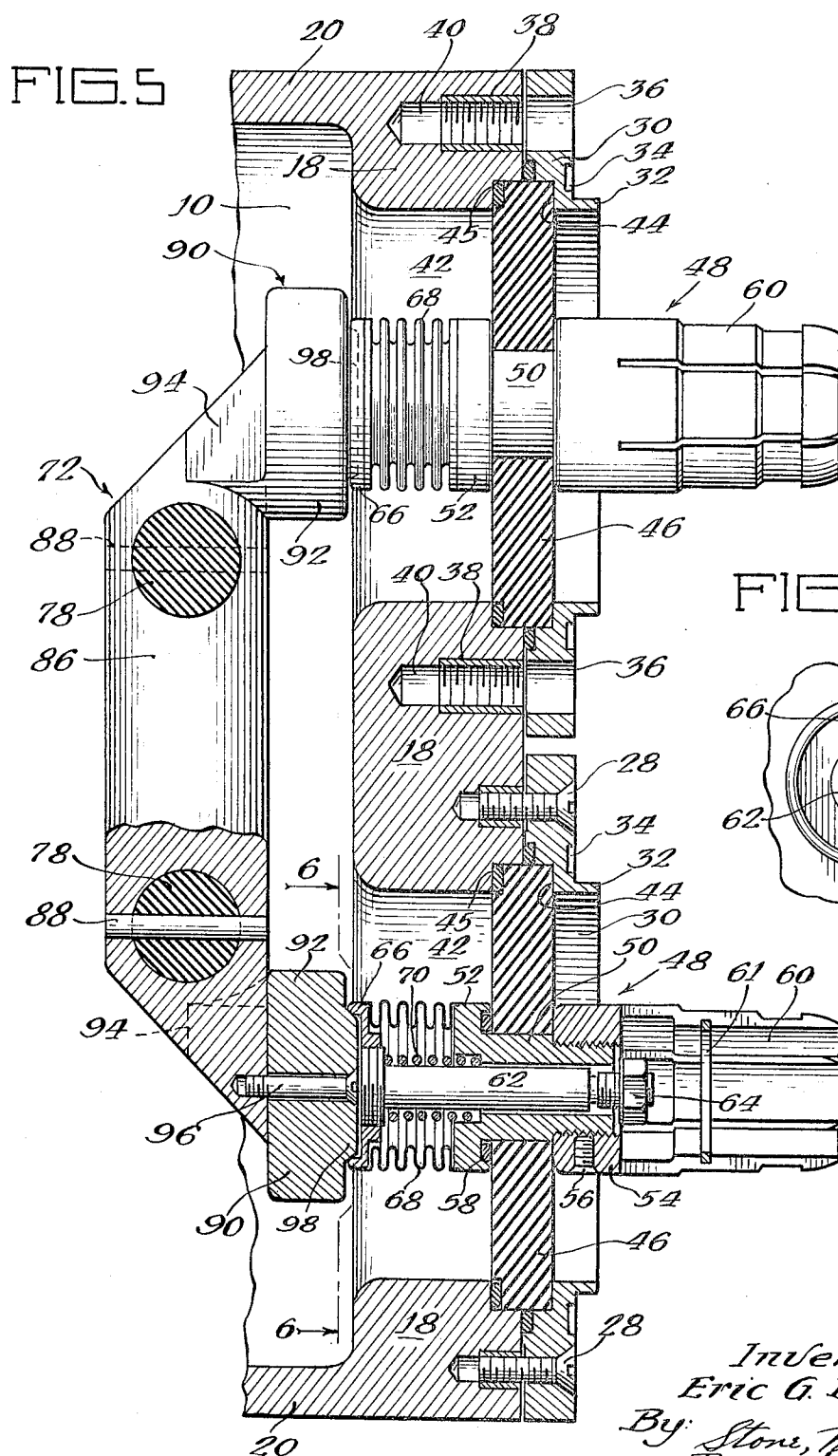
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COAXIAL TRANSFER SWITCH

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4 Sheets-Sheet 4



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COAXIAL TRANSFER SWITCH

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16 Claims. (Cl. 333-7)

This invention relates to high-frequency switches and more particularly to a coaxial transfer switch for use at high frequencies.

A satisfactory transfer switch is required or desirable in various types of high-frequency systems, for example, where a transmitter and a receiver are to be simultaneously alternated in connection to two antennas.

In systems of this type, using coaxial transmission lines operated at high frequency, it has heretofore been customary to perform such switching operations manually, by manipulation of suitable coaxial terminal boards employing coaxial line segments manually manipulated to bridge appropriate terminals, or to use a relatively complex switching network. Where high-power signals are employed, such solutions to the switching problem are not completely satisfactory, since the coaxial lines which must be employed to meet the voltage breakdown conditions imposed by such operation are large and bulky, and the provision of conventional coaxial switches suitable for the purpose, along with the dummy terminations and similar paraphernalia associated with conventional switching systems employed, is extremely complicated and expensive.

A practical transfer switch for these purposes, suitable for motorized or manual operation, has a number of requirements which are achieved in a novel manner in the present invention. It is of course required that no substantial impedance discontinuity be introduced by the switch, nor is any substantial signal attenuation permissible. Since the coaxial lines commonly employed for such uses are gas-filled, the switch is desirably capable of being isolated from the coaxial lines connected thereto as regards gas flow, and should itself be capable of being independently filled with gas in order to permit maintenance of high breakdown voltage characteristics without unduly enlarging the dimensions of the switch. Cross-talk between the two signal channels formed in any switching position must be minimized. In addition, the overall size of the switch must be held to reasonable limits, and the bulk and complexity of the parts moved in a switching operation must likewise be not unduly large in order that the switch can be operated either manually or by a motor or relay mechanism of a capacity which is not excessive.

The above advantages are obtained to a remarkable degree in the switch of the present invention by various features of construction, taken both individually and in combination, which are best understood by consideration of a particular embodiment of the invention incorporating the various features of construction which produce the overall result of provision of a practical coaxial transfer switch for use over a wide range of frequencies, without undue cost or bulk. Such an embodiment is shown in the annexed drawing, in which:

FIGURE 1 is a top plan view of a coaxial transfer switch made in accordance with the invention (it being understood that the face of the switch illustrated, bearing the input and output terminals for the attachment of coaxial lines, is arbitrarily referred to as the top or front herein for convenience of description, the switch being operable in any position);

FIGURE 2 is a sectional view taken along the line 2-2 of FIGURE 1 in the direction indicated by arrows;

FIGURE 3 is a horizontal sectional view taken along the line 3-3 of FIGURE 2 in the direction indicated by arrows;

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FIGURE 4 is a view in end elevation of the rotary or movable portion of the switch;

FIGURE 5 is a sectional view taken along the line 5-5 of FIGURE 1 in the direction indicated by arrows, certain of the parts being shown in elevation and others broken away in section to illustrate the construction with greater clarity;

FIGURE 6 is a fragmentary view in end elevation of a switch contact employed in the construction;

FIGURE 7 is a fragmentary sectional view illustrating the manner of grounding the operating shaft of the switch while leaving rotary and reciprocal motion thereof unimpeded; and

FIGURE 8 is a view in section taken along the line 8-8 of FIGURE 7.

The switch is incorporated in a generally square relatively shallow housing 10, the enclosure of which is completed by a cover or back plate 12. The shallow generally square cavity thus formed is of transverse dimensions substantially greater than twice its depth, and preferably at least four times its depth, for reasons to be discussed later in connection with other aspects of dimensional selection. The cover plate 12 is in turn backed by a motor drive housing 14 (shown only fragmentarily, since the design of this portion of the illustrated assembly constitutes no part of the present invention) containing a suitable mechanism (not illustrated) for driving the shaft 16 of the switch in the desired cycle of motion to be later described. The outer end of the shaft is journaled in the top or front face portion 18 of the housing 10, which is formed integrally with the sidewall 20, for example, in the form of a single casting. The corners 22 of the switching cavity are rounded for purposes to be later described.

Bolts 24 and nuts 26 secure the cover plate 12 to the housing 10, a ring seal 27 being interposed at the periphery of the interface. Screws 28 secure to the outer face of the front or top of the housing annular flange fittings 30 formed with ferrules 32 and O-ring seats 34, and apertured at 36 to pass appropriate bolts (not shown) into threaded inserts 38 in bores 40 in the front face 18 of the housing for the attachment of the conventional coaxial line outer conductor connecting flanges of the lines with which the switch is used.

The top or front face 18 is formed with four large apertures 42 near the four corners of the square cavity, and concentric with the rounding thereof. Positioned between inwardly facing shoulders 44 and outwardly facing shoulders 45 on the abutting surfaces of the flange fitting 30 and the front portion 18 of the housing are annular insulator discs 46, in the center of which are fixed contact assemblies generally indicated by the numeral 48.

Each contact assembly 48 has a coupler bushing 50 having a head 52 at the inner end, a nut 54 engaging the threaded stem of the bushing and locked in position by a set screw 56 and cooperating with the head 52 to securely mount the bushing 50 in the insulator 46, an O-ring 58 being interposed between the head 52 and insulator 46 to form a gas-tight seal and also to prevent undue strain on the insulator both in clamping of the contact assembly into position and in the operation of the switch, to be described later. A split or segmented spring connector 60, provided internally with a spreading ring 61, is formed integrally with the nut 54, serving for the connection of the inner conductor of the coaxial line (not shown).

A guide rod 62 threaded at the outer end and having thereon a nut and washer assembly 64 has its shank extending loosely through the bushing 50 and is threadedly secured at its inner end to a shallow cup-shaped contact disc 66, this latter connection being suitably soldered to make a unitary gas-tight construction. A bellows 68, of

suitable metal such as bronze or brass, has its respective ends securely joined by silver solder to the head 52 of the bushing 50 and to the periphery of the contact disc 66. A coiled spring 70 is under compression between the bushing 52, which is internally recessed at its inner or lower surface surrounding its central aperture to permit the use of an elongated spring 70, and the unitary end contact formed by the disc 66 and the inner end of guide rod 62. The spring 70 thus urges the inner end of the contact assembly 48 into the interior of the cavity, such motion being limited by abutment of the nut and washer 64 against the outer end of the bushing 50 during portions of the cycles of operation of the switch in which the inner end of the contact assembly is not engaged by the rotary contact assembly 72 now to be described.

The rotary contact assembly, generally designated by the numeral 72, is mounted on the shaft 16 by the means of a hub block 74 formed integrally with an isolating vane 76 which is of a length very slightly smaller than the square dimension of the housing cavity. As best seen in FIGURE 2, the vane 76 is somewhat smaller than the housing cavity in the shallow dimension of the latter to permit small reciprocating motion of the shaft as later to be described. Insulator bars 78 extend through apertures 80 in the block 74 in the direction perpendicular to the vane 76, and are secured by bolts 82, the block 74 being slitted at 84 between the clamping portions, formed by the intersection of the circular apertures 80 with the faces of the block parallel and adjacent thereto, and the central vane portion, to permit secure clamping of the insulator bars 78. The ends of the insulator bars are seated in socket bores in conductor rods 86 which extend parallel to each other and to the vane 76 and perpendicular to the bars 78, fastening of the bars 78 in the bores being made by pins 88.

On the ends of the rods 86 are contact members 90 each having a main or body contact portion 92 and a stem portion 94. The shape of the end portions of the U-shaped bridging members formed by each rod 86 and its associated end contacts, as shown in the drawing, may best be understood from a description of the manner in which the assembly is fabricated. Prior to assembly, the end of the rod 86 is a right cylinder, i.e., merely a rod cut off from a longer length with a transverse cut. The stem portion 94 is originally formed by machining flat surfaces 95 on opposite sides of the cylindrical piece from which the contact 90 is formed. The upper end of the stem (considering the orientation of FIGURE 4) is then machined to form a round concavity receiving the rod 86. The contact is then secured to the rod by a screw 96 (FIGURE 5), suitable silver solder also being employed to make a unitary assembly. A 45° bevel is then formed on the end of the now unitary rod and stem to produce a construction for the U-shaped bridging member in which the short arms of the U formed by the body portions 90 of the contact are of greater diameter than the round adjoining rod 86, the ends of which are beveled to a 45° angle. The contacting surface of the body portion 92 is formed with a seat 98 beveled between diameters smaller than, and greater than, the lip of the cup-shaped contact disc 66.

The moving contact assembly thus comprises two parallel bridging contacts having contacting ends forming a square coincident with the square formed by the fixed contact assembly 48. The hub 74 of the rotary contact assembly is keyed to the shaft 16 at 100 and held in place by a nut 102 on the shaft, the end of which is journalled in a bearing 104 in the front portion 18 of the housing, and the opposite portion of which extends through a bearing 106 in the cover plate 12 into the drive mechanism housing 14. The points of entry of the shaft 16 into the opposite walls of the housing are provided with grounding plates 108 and 110 (FIGURES 2, 7 and 8) having spring fingers 112 surrounding and contacting the shaft to ground the shaft, and thus the vane 76, to

the housing. The clearance at 116, provided by the fact that the vane 76 does not extend all the way across the cavity in the small dimension of the latter, permits a small amount of reciprocation of the shaft 16 by the mechanism in the housing 14 as the initial and terminal motions of a switching operation.

In each operation of the switch, the rotary assembly 72 is first slightly retracted to disengage the fixed and movable contacts, then rotated by 90°, the outer portions of the movable contacts 90 following the circular course 118 shown in dotted form in FIGURE 3 of the drawing, and the outer ends of the vane 76 describing substantially the same path, each 90° rotation reversing the connections of input lines connected to one set of diagonally opposed terminals and output lines connected to the other diagonally opposed pair. It will be noted, of course, that such a reversal occurs irrespective of the direction of rotation so that no reversing mechanism is required to be incorporated in the drive means in the housing 14. For convenience of inspection and servicing, the switch housing 10 is provided with access ports 120 capped at their outer ends with suitable removable gas-tight caps (not shown), the discontinuity in the cavity walls formed by these ports having no substantial effect on the electrical performance, for reasons to be described below in connection with certain critical factors of construction. As will be noted in the drawing, suitable O-rings are provided at various interfaces, in addition to those described above, to make the cavity of the switch gas-tight.

The structural portions of the embodiment illustrated in the invention having thus been described, the purpose and advantages of the various construction features may now be set forth along with the dimensional considerations required in the most advantageous embodiments of the invention. The external portion of each of the terminals is designed for exact correspondence with the dimensional features of the coaxial line of the size for use with which the switch is intended. The sealed construction as illustrated, and as described above, isolates the gas content of the cavity from those of the coaxial lines employed therewith, so that all lines are mutually isolated in this respect from each other and from the switch, which may accordingly be operated with any desired gas filling (introduced through ports 120 or otherwise).

The reduced diameter of the inner conductor at the body portion of the bushing 50, and the increased diameter of the inner conductor produced by the shoulders between which the periphery of the insulators 46 is clamped, are compensated by the increase in dielectric constant which occurs at this point because of the insulator, so that the characteristic impedance of the line at this point continues to match that of the coaxial line employed. On the inner side of each insulator, the diameters of the inner and outer conductors again match those of the coaxial line. The hollow bellows 68 act electrically as solid conductors at high frequencies because of the skin effect. Loss of continuity at the interface between the fixed and movable contacts is assured by the cup-shaped construction of the disc 66 and the beveled construction of the seating portion of the movable contact, guaranteeing firmness of contact at this peripheral portion of the mating, which is the critical portion, again because of skin effect.

The firm contact engagement is maintained by the spring 70, the yielding construction of the bellows, when coupled with the substantial clearance between the guide rod 62 and the aperture in bushing 50 assuring automatic alignment of the cup-shaped disc 66 and the beveled seating portion 98 with substantial tolerance in manufacture of all the parts, because of the slight rocking of the disc 66 which will automatically produce full peripheral contact in the event that slight misalignment should occur. It will be noted that the bellows 68 forms an important part of the gas seal which separates the gaseous medium in the switch cavity from that within the coaxial line attached.

With the contacts seated, the point of joinder is substantially flush with the front face of the main body of the cavity. At this point, the apertures 42, which form the outer conductors, open into the main body of the cavity. In order to preserve the constant impedance characteristic, the body 92 of the moving contact 90 is of substantially larger diameter than the central conductor of the stationary contact assemblies. The geometry of the transmission system at this point becomes of a type incapable of ready calculation of impedance because of the complications introduced by more remote portions of the housing, but may be closely approximated by considering the grounded conductor at this point as being the adjacent quarter-circle rounding of the corner of the cavity, which is concentric with the contact. The determination of the exact size of the enlargement is preferably determined experimentally by mismatch or reflection measurements in design of switches for various types of coaxial lines.

Adjacent to the contact bodies 92 on the ends of the bridging assemblies are the transition portions whose design for any given impedance, etc., is best understood by first considering the transmission configuration at the central region of the bridging member. In the seated position of the contact, the rods 86 are substantially midway between the walls defining the small dimension of the cavity. The dimensioning of the cavity earlier described produces the effect that the rods 86 are much closer to the walls last mentioned than to the closest adjacent wall defining the square or to the vane. Thus for practical purposes, the transmission in this portion is substantially in the configuration of a wire or rod extending midway between two parallel infinite plates, so that the design criteria for obtaining any desired impedance in this region are known. It will be noted that the difference in effective distances just discussed prevents any serious impedance discontinuity due to the presence of the ports 120, the block 74, or the shaft 16.

The beveled compensation or transformation portions at the ends of the rods 86 are designed for the dual purpose of preventing reflections in each right angle bend in the direction of transmission, and also to provide transformation between any impedance differences which may exist, despite care in design, between line impedances in the two directions of transmission, and compensate for any inaccuracy of matching inherent in the fairly complex field shapes. Here a few experiments may be required in designing new constructions for optimum operation, various exact locations of the bevel being employed until fully satisfactory reflection elimination is obtained.

The vane serves to isolate the two transmission channels formed in any position of the switch. It is grounded to the housing through the shaft as previously indicated. This construction is adequate for prevention of cross-talk between channels at any but the highest of frequencies. Of course, for operation at frequencies at which the leakage past the vanes becomes intolerable, suitable spring contacts or similar provision may be made for further grounding of the vane and completion of the barrier between the two transmission zones.

From what has been said, persons skilled in the art will be enabled to construct a variety of particular designs of coaxial switches, particularly transfer switches, employing the teachings of the invention, for use with coaxial lines of a wide spectrum of characteristics and details of construction, some embodiments of the invention obviously being far different in appearance from that herein illustrated. A typical example of a commercial embodiment of the invention, made in accordance with the annexed drawing, may nevertheless be of value as a guide in designing other embodiments. This embodiment, designed for $3\frac{1}{8}$ " coaxial line with 50 ohm impedance, has a cavity $9\frac{13}{16}$ " square with a depth of 2.47", the input outer conductor apertures being slightly over 3" with the annular insulators having an outer diameter slightly under $3\frac{1}{2}$ "

and an inner diameter of .845", the portions of the inner conductor other than that surrounded by the insulator (commercially known as Rexolite) being slightly over $1\frac{1}{4}$ ". The movable contact body is 1.8" in diameter with a thickness of the contacting portion of approximately $\frac{5}{8}$ ", the width of the stem formed by flattening opposite sides being approximately 1.3" to form a semicircular receptacle for the bridging rod of the same size. The 45° bevel at the ends of the bridging rod (and the stem) terminates approximately half way between the center and the outer periphery of the upper surface of the contact body. The square formed by both the fixed and the movable contacts is slightly over 5.3" on a side. The vane is slightly over 2" in width, thus permitting the motion of the movable assembly desirable for firmly seating the contacts and also permitting the vane to clear the fixed contacts in the course of operation of the switch, despite the fact that they extend beyond the flush position to a slight degree when not forced back by the movable contacts. Of course, the clearance requirement is not high, since the washer and nut stop provided on each center conductor terminal assembly prevents the bellows from extending substantially into the cavity. The embodiment just described produced an isolation between channels of about 60 db at frequencies as high as 480 mc., with a maximum VSWR of 1.04 over the same frequency range.

As previously indicated, persons skilled in the art will readily construct many embodiments of the invention far different from that illustrated, but nevertheless employing the teachings of the invention. Accordingly, the invention shall not be considered as limited by the particular embodiment illustrated, but is defined in the annexed claims.

What is claimed is:

1. A coaxial transfer switch comprising a conducting cavity, a rotor in the cavity, four coaxial connectors on one face of the cavity having inner and outer conductors insulatedly supported symmetrically about the rotor in the form of a square, two parallel bridging conductors each adapted to contact a pair of inner conductors forming one side of the square and insulatedly mounted on the rotor on opposite sides thereof, a conducting shield on the rotor midway between the bridging conductors and parallel therewith and extending substantially across the cavity wholly in the region between the bridging conductors, and means for grounding the shield to the cavity, each bridging conductor forming with the opposed faces of the cavity and the adjacent side wall of the cavity and the shield a coaxial transmission path isolated from the other by the shield, each bridging conductor being the inner conductor of a coaxial transmission path and the shield forming only the portion of the outer conductor in the direction of the other bridging conductor, the remainder of the outer conductor of each coaxial transmission path being different portions of the faces and side walls of the cavity in each rotary position of the switch.

2. The switch of claim 1 wherein the bridging conductors are substantially midway between the inner surfaces of the front and rear of the cavity, the spacing between the bridging conductors and the front and rear being substantially smaller than the spacing between the bridging conductors and the shield and the sidewall of the cavity.

3. A coaxial switch comprising a conducting cavity, a rotor in the cavity, at least four coaxial connectors having outer conductors grounded to the cavity and having stationary inner conductors insulatedly supported symmetrically about the rotor, at least two bridging conductors each adapted to contact a pair of inner conductors and insulatedly mounted on the rotor in positions wherein the respective bridging conductors contact different pairs of inner conductors in each position of the rotor, at least one conducting shield on the rotor substantially entirely in the region between the bridging conductors and extending from the rotor substantially to the side walls of

the cavity to divide the cavity into portions each containing a bridging conductor conductively enclosed only by the walls of the cavity and the shield and forming a transmission path of impedance matched to that of the connectors, and means for grounding the shield to the cavity, each bridging conductor being the inner conductor of a coaxial transmission path and the shield forming only the portion of the outer conductor in the direction of the other bridging conductor, the remainder of the outer conductor of each coaxial transmission path being different portions of the faces and side walls of the cavity in each rotary position of the switch.

4. The switch of claim 3 wherein the bridging conductors are substantially U-shaped, having contact arms at each end and an elongated straight interconnecting conductor, the latter being substantially equally spaced from the front and rear walls of the cavity.

5. The switch of claim 3 wherein the bridging conductors are substantially midway between the inner surfaces of the front and rear of the cavity.

6. The switch of claim 3 wherein the inner end portions of the stationary inner conductors comprise hollow flexible tubular conductive members.

7. In a coaxial switch, a cavity having a rotor therein, a plurality of coaxial connectors having outer conductors grounded to the cavity and inner conductors extending into the cavity to form a regular polygon having the rotor at its center, a bridging conductor of a length equal to a spacing between inner conductors insulatedly mounted on the rotor to contact pairs of inner conductors, a conducting shield extending from the rotor substantially entirely on one side of the bridging conductor substantially to sidewalls of the cavity adjacent to the ends of the bridging conductor and shielding the bridging conductor from the portion of the cavity on the opposite side of the shield and rotatable with the rotor, and means for grounding the shield to the cavity, the cavity walls and the shield comprising substantially the sole conductive electrical enclosure of the bridging conductor and forming a coaxial transmission path between connectors.

8. In a coaxial switch, a cavity, a plurality of coaxial connectors having outer conductors grounded to the cavity and inner conductors extending into the cavity, a rotor, a bridging conductor mounted on the rotor for selective engagement of inner conductors, a conducting shield mounted radially on the rotor substantially entirely on one side of the bridging conductor and insulated from the bridging conductor and extending substantially to the sidewall of the cavity, and means for grounding the shield to insulate the transmission path defined by the bridging conductor from coaxial connectors other than those to which the bridging conductor is connected, the cavity walls and the shield comprising substantially the sole conductive electrical enclosure of the bridging conductor and forming therewith a coaxial transmission path of an impedance matching the connectors.

9. In a coaxial switch comprising a cavity, a coaxial connector having an outer conductor grounded to the cavity, an inner conductor, and insulating mounting means receiving the inner conductor in position with its end in the cavity, and a movable contact within the cavity adapted to contact the inner conductor within the cavity, the improved construction wherein the inner end portion of the inner conductor comprises a hollow longitudinally flexible bellows having a contact member on the end thereof and sealed thereto.

10. The coaxial switch construction of claim 9 wherein the cavity has an elongated aperture therein, the outer end of the bellows being secured in fixed relation to the mounting means in the outer portion of the aperture, the

bellows having therein a spring under compression urging the contact member inwardly and having means for limiting extension of the bellows to the region wherein the contact member is substantially flush with the inner surface of the cavity.

11. The coaxial switch construction of claim 9 wherein the movable contact and the contact on the end of the bellows have mating outwardly extending annular surfaces near the periphery thereof, one of the surfaces being beveled to assure full peripheral contact by deformation of the bellows.

12. A coaxial connector having an inner conductor comprising a hollow flexible conductive tubular enclosure having a contact cap on one end and a bushing on the other end, a spring within the tubular enclosure under compression between the contact cap and the bushing and a guide member loosely slidable in the bushing and secured to the contact cap to hold the contact cap in general alignment while permitting slight rocking motion of the contact cap for exact alignment.

13. The connector of claim 12 having a stop member abutting the outer surface of the bushing to limit extension of the bellows under the action of the spring.

14. A coaxial connection having, in combination with an inner conductor as set forth in claim 12, a mating inner conductor in endwise contact with the contact cap, one of the contacting portions having an annular protrusion on the edge portion thereof making peripheral contact with the other.

15. A coaxial switch comprising a hollow conducting cavity, coaxial connectors terminating in the cavity, bridging members movable within the cavity to selectively interconnect inner conductors of the connectors and a shielding member substantially entirely between the bridging members and grounded to the cavity, the walls of the cavity and the shielding member comprising sub-bridging members and forming therewith coaxial transmission paths of substantially the same impedance as the connectors, the shield forming only one portion of each such enclosure, the remainder of each respective enclosure being different portions of the walls of the cavity in each rotary position of the switch.

16. A coaxial switch comprising a conducting cavity of substantially square cross-section, four coaxial connectors disposed in the form of a square on a face of the cavity, a shielding member bisecting the cavity and grounded to the walls thereof, bridging conductors on opposite sides of the shielding member connecting respective pairs of inner conductors of the connectors, and a rotary member mounting the shielding member and bridging conductors to reverse the connections of the connectors, the walls of the cavity and the shielding member comprising substantially the sole conductive electrical enclosure of the bridging conductors and forming two coaxial transmission paths of substantially the same impedance as the connectors.

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